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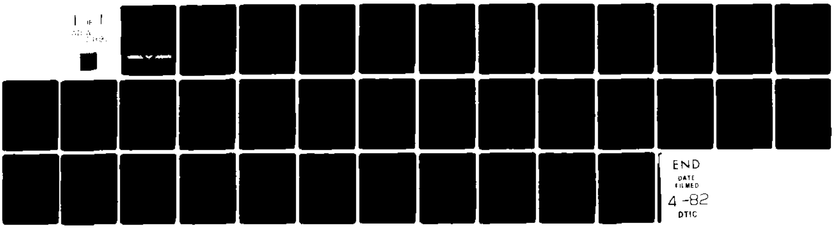

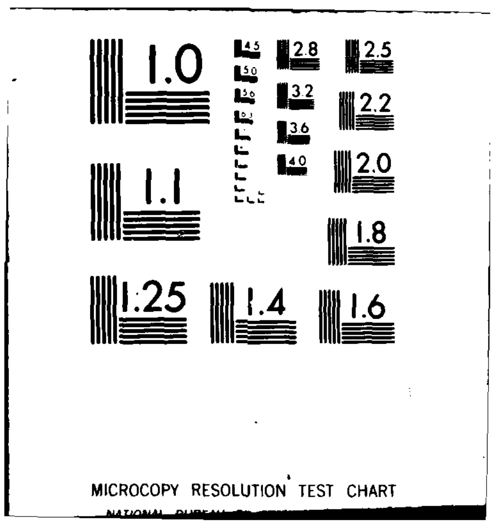
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REPORT NO T 9/80

SIMULATED, SUSTAINED COMBAT OPERATIONS IN THE FIELD ARTILLERY FIRE DIRECTION CENTER (FDC): A MODEL FOR EVALUATING BIOMEDICAL INDICES

US ARMY RESEARCH INSTITUTE OF ENVIRONMENTAL MEDICINE
Natick, Massachusetts

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Military biomedical scientists must quantify how biological and behavioral phenomena influence operational capability and military effectiveness. To this end, four 82d Airborne Division FDC teams were tested in simulated, sustained combat operations. Role players interacted from scripts describing mission demands matched across time. Biomedical data were also obtained. All teams performed intense workload operations, without shifts. Teams 1 & 4 anticipated a single 86 h challenge; they discontinued after 48 & 45 h. Teams 2 & 3 experienced two 38 h challenges separated by 34 h rest; however, a

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Team 3 member withdrew after 6 h (second challenge). Accuracy for on-call missions against preplanned targets suffered in Teams 1 & 4. After 36 h, much preplanned target processing was never completed, not even for priority targets. In the second challenges, Teams 2 & 3 showed reduced preplanning efficiency after 24-36 h. Verbal communication units decreased during lulls; larger task-related ratios preceded performance deteriorations. The ratios of Teams 1 & 4 increased until 24-30 h. Later, preplanning activities deteriorated markedly and communications ratios decreased, suggesting conservation and/or unwillingness (inability) of team members to sustain performance. Thus, simulation of an actual Army team task provides a framework for validating biomedical indices. The impact of biomedical, behavioral, biochemical, and social changes can be demonstrated by relating them to FDC operational indices. Research findings from this program are applicable to military users, planners, and modelers.

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Technical Report

No. T 9/80

Simulated, Sustained Combat Operations in the Field Artillery Fire Direction Center (FDC): A Model for Evaluating Multivariate Indices

by

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Natick, Massachusetts 01760

FOREWARD

The modern battlefield will make many new and unprecedented demands upon the soldier. Future confrontations are likely to be intense, quick paced, and continuous, with few opportunities for rest and sleep. The ability of the soldier to operate and be effective under such conditions is of great importance to military planners, doctrine developers, and militay units who train for such contingencies. This project was an attempt to determine the types and magnitudes of behavioral, team, and operational changes encountered in Field Artillery Fire Direction Center Teams during intense, sustained, simulated combat operations.

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ABSTRACT

Military biomedical scientists must determine and quantify how biological & behavioral phenomena influence operational capability & military effectiveness. To this end, four 82d Airborne Division FDC teams were tested in simulated, sustained-combat operations. Role players interacted from scripts describing mission demands matched across time. Communication data were also obtained. All teams performed intense workload operations, without shifts. Teams 1 & 4 anticipated a single 86 h challenge; they discontinued after 48 & 45 h. Teams 2 & 3 experienced two 38 h challenges separated by 34 h rest; however, a Team 3 member withdrew after 6 h (second challenge). Accuracy for on-call missions against preplanned targets suffered in Teams 1 & 4. After 36 h, much preplanned target processing was never completed, not even for priority targets. In the second challenges, Teams 2 & 3 showed reduced preplanning efficiency from 24-36 h. Verbal communication units decreased during lulls; larger task-related ratios preceded performance deteriorations. The ratios of Teams 1 & 4 increased until 24-30 h. Later, preplanning activities deteriorated markedly & communications ratios decreased suggesting conservation and/or unwillingness (inability) of team members to sustain performance. Thus, simulation of an actual Army team task provides a framework for validating multivariate indices. Biomedical, behavioral, biochemical, & social variables can be evaluated by relating them to FDC operational indices. Research findings from this report should be applicable to military users, planners, and modelers.

1. INTRODUCTION

BACKGROUND

When military biomedical research addresses practical problems, the scientist must evaluate if biological and behavioral phenomena have real-world consequences for military planners and users. In addition, findings must be translated into a suitable framework so planners can anticipate how such consequences will degrade (or sustain) the operational capability and effectiveness of military personnel. In evaluating conditions which affect human performance, the scientific literature (1-5) indicates the importance of task, personnel, and organizational variables. These include: task complexity, feedback, pacing, level of training, intrinsic task interest, experience, motivation, and social factors. Such variables are considered critical determinants of performance capability under a variety of conditions. Furthermore, in both modern industrial society and in the Armed Forces tasks are increasingly organized around teams rather than individuals. Concerns are often expressed as to the generality and predictive validity of past studies which have not incorporated variables inherent in many real-world tasks.

To address these issues and provide a framework for communicating research results to the military community, the Field Artillery Fire Direction Center (FDC) was selected by the US Army Research Institute of Environmental Medicine (USARIEM) as a model for study. It was postulated that such issues could be addressed in a laboratory simulation which would use actual Army teams performing their normal functions. This would permit control and replication of environmental and situational conditions together with measurement and correlation of mission effectiveness, behavior and biological

processes (3,4). This approach would also capitalize on pre-existing training, professional pride, social support and military-task organization. Such factors are critical in the study of group-task performance, the contribution of individual performance to system (team) output (3,4) and physiological and psychological responses to stress (5).

The FDC team seemed well-suited for scientific study and laboratory simulation. Critical determinants included: 1) FDCs are common and critical to successful ground-combat operations, 2) FDC teams are located immediately behind the forward edge of the battle area and are exposed to most extant stresses, 3) FDCs include tasks common to other command/control and communication elements, 4) Detailed scenarios can be developed to provide calibrated performance demands, 5) Quantifiable measures of both individual and team performance can be derived, 6) The compactness of FDCs allows collection of a wide range of biomedical and psychosocial data, 7) Many variables which influence performance are inherent in FDCs, and 8) FDCs provide a performance paradigm with operational criteria, recognized by the military community, for correlation with various data arrays.

FDC TASKS & ORGANIZATION

In the Field Artillery, the FDC is a service center which receives requests from various groups who require artillery shells to hit target areas. These targets are typically kilometers away and out of view of the guns. In the Artillery of the US Army (battery level) a team of 5 to 7 individuals process such requests. Non-computerized FDCs have existed since World War I and have evolved to insure that performance is robust to adverse conditions. Roles, tasks, communication sequences and content, error detection and resolution capabilities, information-readback procedures, etc. are well specified and practiced (see

Appendix, Table AI). To understand variations in system output, individual task contributions and interactions can be analyzed (6,7). Many FDC tasks are similar to classical performance tests. Although FDC tasks are sometimes embedded in contexts which limit interpretation, they can be compared with the scientific literature.

2. METHODS

STANDARDIZATION OF TASK DEMANDS

Much precision of conventional laboratory paradigms was applied to the complex mission demands of the Field Artillery to reduce extraneous variance so FDC performance and other indices could be documented. This methodology was incorporated into a detailed script ("scenario") of radio messages which provided the task demands, as well as the supporting documents, e.g. map overlays and unit SOP. The scenario represented a tactical battle played on 1:50,000 scale maps and followed current doctrine for light infantry with armored cavalry opposing a well-equipped screening force. Tasks demands were communicated to the FDC over three simulated radio nets; other roleplayers provided the telephone communications of the nearby gun crews and controlled the guns' sound effects.

To permit performance assessment with time the scenario was organized into equivalent 6 h epochs of mission demands. In each 6 h, events of differing importance, complexity, and urgency, requiring different individual and team responses, recurred frequently to permit event pooling. Major mission demands included (see Appendix, Table AII): 1) Unplanned Missions — Calls for Artillery fires on a target which were often followed by several subsequent adjustments, i.e., repetitions with small variations. 2) Preplanning — These tasks were initiated by the receipt of encoded preplanned target messages. All team

members were involved, but since task processing was somewhat sequential, required actions from most personnel were delayed. 3) Prioritizing -- At any time, 2 of 16 preplanned targets were designated as having priority to emphasize that an especially rapid and accurate response might be required on these targets. 4) On-call Missions — These demands were calls for Artillery fires on preplanned targets. Typically, they occurred at least 15 min after receipt of encoded preplanned target messages. 5) Revising — There were 12 initial preplanned targets encountered at the beginning of each 6 h epoch. Task demands differed somewhat from those of preplanning. The targets were preplotted on the chart sheets so the chart operators did not have to plot them nor did the radio operator have to decode them. 6) Updating — Updating should have occurred about 150 min into each epoch. It was to improve ballistic correction factors on 12 preplanned targets. 7) Multiple Mission Sequences — Periods of intense fire mission activity included: unplanned missions, on-call missions, non-standard missions, adjusts and shifts. 8) Lulls — These were two 12 min intervals in which no new mission demands were sent to the FDC although irrelevant radio traffic continued. These events created a standardized setting, embedded among other demands, where social interactions might be more likely to occur. Such intervals were also used to complete prior preplanning activities.

EXPERIMENTAL DESIGNS

Two designs, differing in the number of sustained challenges and their durations, were utilized. Design I had a single 86 h operational challenge; Design II had two 38 h challenges separated by a 34 h rest interval. Both designs had identical pre-challenge familiarization and training trials. Design I was essentially an "open ended" challenge since 86 h was judged to be beyond the limits for sleep deprived subjects to perform such cognitive tasks. Design II was to evaluate the FDC model in a repeated-measures design.

SUBJECTS & SIMULATION FACILITIES

The 5-man FDC teams were fully informed volunteers, aged 18-24, from two battalions of the 82nd Airborne Division. These teams normally rely on manual fire direction procedures exclusively, without the assistance of digital computers. Manual FDC equipment was assembled in a tent inside a 6.1 x 2.7 x 2.4 m climate-controlled chamber at USARIEM. Temperature was maintained 20-24°C, relative humidity 35-50%, and lighting was superior to field FDCs for continuous videotaping. Each subject wore a microphone and transmitter for individual-voice reproduction, a physiological cassette recorder, wrist-activity sensor, ECG electrodes and, in some instances, EEG electrodes. Audio from each field radio, the FDC-gun telephone line, and from each FDC team member, as well as a time code, were recorded on separate channels of an audio recorder for post-study analyses.

SIMULATION PROCEDURES

All teams received a 5 h orientation followed by 3 days of simulation training (8 h/day) at the scenario work load used subsequently. Teams 1 and 4 were each told they would undergo a single 86 h challenge. Teams 2 and 3 were advised they would experience two 36-42 h challenges separated by a 30-36 h rest; each challenge actually ran for 38 h. All subjects were instructed not to set shifts or to sleep. Teams 2 and 3 were instructed not to rotate jobs. Teams 1 and 4 received no such instructions. In the simulation, each team was challenged by the scenario demands; performance-contingent positive and negative feedback for accuracy and timeliness was given to the FDC by simulation roleplayers. All operational challenges began at 7 a.m. Every 6 h during a simulated tactical move approximately 48 min were spent in nonoperational, administrative activities. Self-report questionnaires were administered,

urine and sometimes blood samples were collected, electrodes and instrumentation were maintained by "field medics" and meals were eaten.

PERFORMANCE ASSESSMENT

Performance indices were derived for system (team) performance. Accuracy and timeliness data were scored from audio recordings. An accuracy deviation, or error, was defined as the algebraic difference (in mils) between an FDC team's firing data and the correct solution as computed manually by the Department of Gunnery, USAFAS. Timeliness was the latency between mission input and a team's output.

COMMUNICATION ANALYSES

Interaction Process Analysis (IPA) was developed by R.F. Bales to assess the quality of interactions in a group (8). The FDC studies provided a unique opportunity to evaluate this non-invasive technique in small Army teams during acute exposure to situational stress and fatigue and to relate IPA trends to operational changes. In IPA, all verbal utterances are divided into communication units (CU). A CU is a group of sounds, words, gestures, etc. that conveys a single thought or action. Each CU is assigned to 1 of 12 categories based on the predominant quality of the interaction.

The FDC teams differed from many of the groups studied by Bales. Since the FDC's highly specified tasks, roles, and task organization generated many task communications which were standard in content and their time sequencing, an additional category, Task SOP, was specified for the FDC analyses. This category was for those CU which were formal communications in the standard, sequential process of computing and transmitting ballistic data. Task SOP CU only included standard task communications.

In the analyses, each team member's vocalizations during the two 12-minute lulls were transcribed from audio records and arrayed in parallel against a common time axis. All verbal utterances were divided into CU and all Task SOP CU were identified. All remaining CU, i.e. All Other CU, were identified and classified into one of Bales's categories. The sender and receiver for each CU were also specified. All information was formatted and encoded for automatic data processing. Video records were viewed prior to scoring each lull.

In the data reduction, group functions were computed for Teams 1, 2, & 4 (Team 3 is in progress). Each function represented the contributions of all 5 members. All CU were categorized as either Task SOP or All Other. To show the relative proportion of each, a ratio was calculated:

$$\text{Task Ratio} = \frac{\text{No. Task SOP CU}}{\text{No. All Other CU}}$$

3. RESULTS & DISCUSSION

OVERVIEW

Other investigators collaborated in the design and conduct of the study, but only selected data obtained by USARIEM investigators will be presented. The teams differed substantially in organizational style, social history, prior experience, and mastery of the simulated mission demands. Generally, Teams 1 and 4 showed less initial mastery and greater performance changes over time (Design I). All teams responded to the competitive challenges and became involved with the simulation (6,9).

Team 1 withdrew from the study at 7 a.m. after 48 h. A chart operator appeared especially sleepy after 42 h, chose to discontinue, and the officer decided that the team should leave together. Team 4 withdrew voluntarily at 4 a.m. after 45 h. The younger enlisted personnel had little field experience and

were very fatigued. The officer was also fatigued from his continuous supervision but persevered until his sergeant prompted him for the decision to stop. Both teams made several errors which "endangered" friendly troops; they had also become deficient in their preplanning and prioritizing. Team 2 showed some deterioration in the second challenge; three team members had slept very poorly the previous evening. Team 3 completed both 38 h trials with little performance deterioration. After 6 h of the second trial, a chart operator terminated; the remaining four continued. They had slept well in the interim.

SYSTEM OUTPUT: ACCURACY

For all teams, accuracy of firing data for unplanned missions was generally maintained even until termination (6). In contrast, accuracy of firing data for preplanned targets fired upon during on-call missions was less for all teams. Accuracy deteriorated with time in Teams 1 and 4; they showed increased 7-14 mil errors. These usually involved omissions of correction factors due to speed-accuracy tradeoffs. Generating preplanned target data required increased processing compared to unplanned missions. In addition, negative (reprimanding) feedback criteria for on-call missions were more demanding, e.g. 20–60 vs 60-180 sec. Teams 2 and 3 each showed some variability in on-call mission accuracy; no progressive deterioration was evident.

SYSTEM OUTPUT: TIMELINESS

Although accuracy for unplanned missions was generally maintained, timeliness suffered in all but Team 3 (6). Latencies for the subsequent adjustments increased more than 35% from initial values of ~ 30 sec during sustained operations for Teams 1,2, and 4. The initial and final 6 h latency differences were statistically significant ($p \leq 0.05$ for Teams 1 and 2; $p \leq 0.01$ for Team 4).

Video review confirmed that speed was sometimes sacrificed for accuracy through increased individual latencies and resolving of differences from double-check procedures. Such changes have tactical significance. Increased latencies would result in reduced effectiveness of Artillery fires on battlefield targets. FDC and battery vulnerability would be increased.

Timeliness, as well as accuracy, for on-call missions against preplanned targets suffered in Teams 1 and 4 (6). Initial median latencies of 8-10 sec increased > 400% after 42 h in Team 1 and 50-400% after 30 h in Team 4 ($p \leq 0.01$). Responses to on-call missions by Teams 2 and 3 were less varied; Team 2's responses increased 30-60% from 18 to 30 h of the second challege ($p \leq 0.05$).

In responding to on-call missions against preplanned targets during the multiple mission sequences, the rapid responses to be realized by preplanning deteriorated markedly in Teams 1 and 4 in those very situations where responsiveness was tactically most crucial. For Team 4, the 300-700% increases began after 24 h but recovered slightly after 36 h. In Team 1, increased latencies (40-300%) occurred from 6-30 h. After 43-45 h, (~2 and 4 a.m.), latencies increased 10-12 times from initial values. Teams 2 and 3 showed some increased variabilities and latencies. It is evident Team 1's median delay of > 300 sec to deliver what Artillery doctrine requires in < 20 sec was a marked change in operational efficiency. Such delays would have serious consequences in combat where rapid delivery of preplanned Artillery fires is essential to suppress hostile, wire-guided weapons.

Preplanning is intended to generate firing data for a preplanned target and send it to the guns before an on-call mission on that target occurs. When preplanning was achieved, response latencies were minimal. If not, data computations were required "on the spot", increased latencies resulted, and teams were more likely to make errors in haste or through deliberate omissions.

SYSTEM OUTPUT: PREPLANNING & PRIORITIZING LATENCIES

Examining various preplanned target processing activities (i.e., preplanning, prioritizing, revising, and updating) suggests how the observed differences in team effectiveness to on-call mission events occurred. It also has the advantage of assessing risk of serious mission failure for the total population of preplanned targets. Operationally, preplanning required processing target messages and sending the firing data for each target to the guns as soon as possible. Preplanning involved all members; each had to complete his work on a target before another could proceed. Hence, individual tasks were delayed. Team members had to schedule time to complete preplanning tasks amidst "breaks" in the action and other demands. Unless completed quickly, other scenario events would inevitably interrupt processing.

Preplanning latencies for the four teams are shown in Figure 1. Teams 1 and 4 showed increased latencies after 18-24 h; these increases were 30-70% greater than initial values. After 36 h, failure to process several preplanned targets characterized performance. After 24 h in the second challenges of Teams 2 and 3 processing times increased. Latencies did not change during the first 38 h challenges, although processing for Team 2 was more varied after 24 h. Team 2 was very proficient; their latencies were approximately 25% those of other teams. Thus, the increased delays in responding to on-call missions (single and multiple mission sequences) in Teams 1 and 4 resulted largely from failure to preprocess data (6). Decreased accuracy resulted from speed-accuracy tradeoffs or from lapses due to haste.

Figure 2 shows the latencies for the prioritizing aspect of preplanned target processing. Prioritizing emphasized some preplanned targets as being more important than others. This task involved specifying to the guns which preplanned target was of greatest importance to the forward observer and

Figure 1. Preplanning latencies for Teams 1, 2, 3, & 4 (top to bottom) are shown as a function of h in the simulation. The squares, with lower and upper points, indicate the 50, 25, and 75th percentiles, respectively. Values plotted above the break on each left ordinate were > 105 min. Also shown are the percent of preplanning demands satisfied for each 6 h.

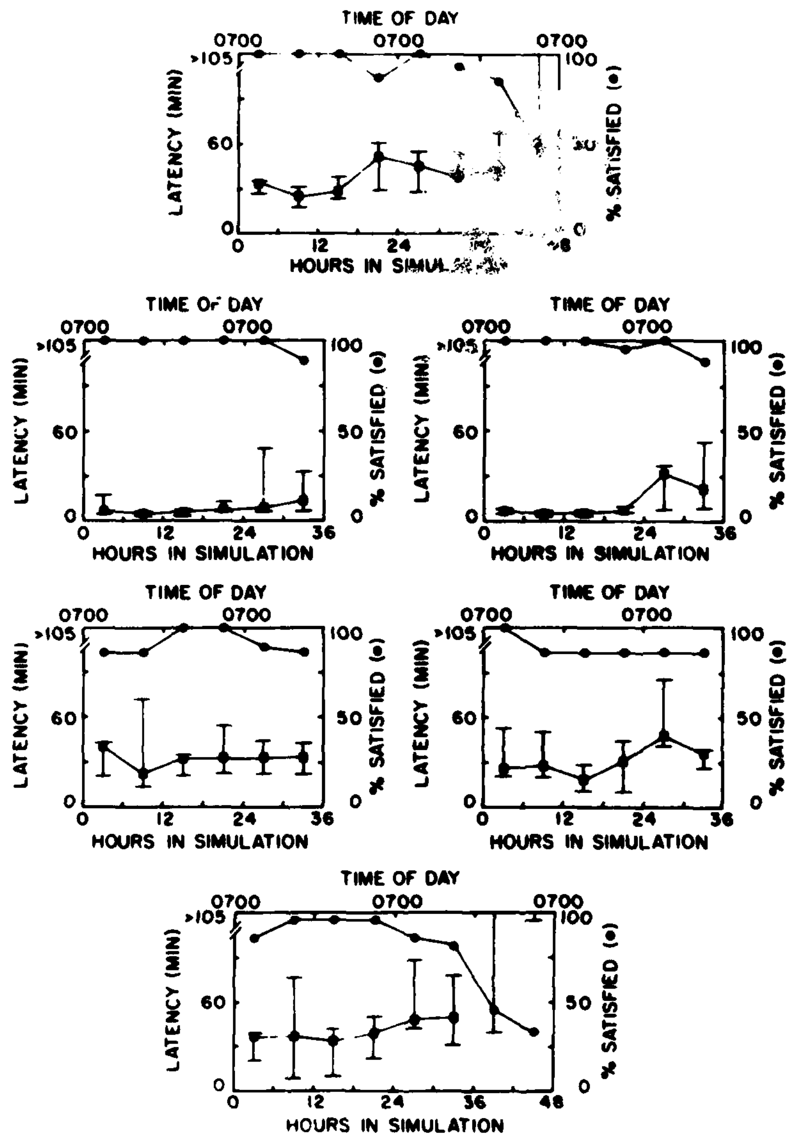
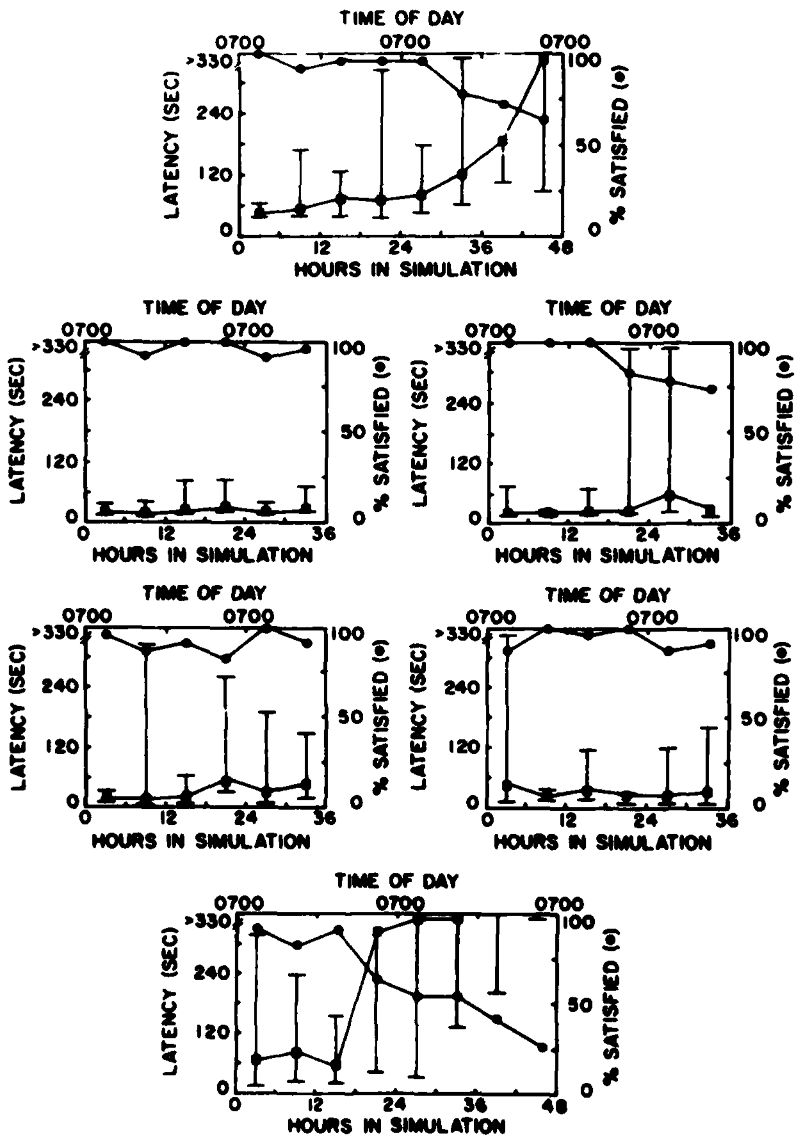


Figure 2. Prioritizing latencies for Teams 1, 2, 3, & 4 (top to bottom) are shown as a function of h in the simulation. The squares, with lower and upper points, indicate the 50, 25, and 75th percentiles, respectively. Values plotted above the break on each left ordinate were > 330 sec. Also shown are the percent of prioritizing demands satisfied each 6 h.



calling ballistic data to the guns, if not communicated previously. Teams 1 and 4 showed increased latencies for prioritizing. Increases, 200 to 600% greater than initial values, were evident after 18 h in both teams. Teams 2 and 3 were more proficient and consistent in their prioritizing. As with Team 2's preplanning trend, prioritizing was also impaired after 24 h in the second challenge.

The percentage of demand satisfied decreased with time in Teams 1, 2 (second challenge), and 4. This occurred even though preplanned data were usually at the guns when a target was specified as priority by the role player. Specifically, for Teams 1, 2, 3, and 4, data were already at the guns on 87, 94, 96, and 67% of the occasions when each team's sergeant failed to specify a target as priority. Although in these circumstances each sergeant needed only to announce the priority target number to the guns, all but one increasingly failed to do so. We suspect attention to detail and involvement in processing task demands increased markedly with time as teams attempted to keep current on their preplanning. Such demands made it more likely that responsible members did not respond to the information when it came over the radio or they subsequently forgot it. Additional analyses will document how this critical performance was not maintained nor compensated for by other team members.

SYSTEM OUTPUT: UNPROCESSED PREPLANNED TARGET DEMANDS

The quantity of work never completed may be more useful as an index of team capacity and performance efficiency than increased errors or latencies. Table I highlights differences between the 4 teams on preplanned target activities. Entries show the percentages of various preplanned target activities and total target processing never completed. Several trends are evident. Total target processing was less adequate at 36 h for Teams 1 and 4 (Design I) than for Teams 2 and 3 (Design II); updating contributed predominately to this trend.

Although one cannot rule out level of training, experience, and organizational variables these and other performance data suggest the uncertainties, expectancies, and demands of an 86 h challenge took an earlier and greater toll on Teams 1 and 4. This observation is further supported by trends in the biochemical data (6). Secondly, Team 4, the least proficient and experienced team, was the team which demonstrated the least adequate total target processing. Lastly, in all 4 teams updating was the preplanning activity most incomplete. It is interesting that updating was the only preplanned target activity done by a single team member (6).

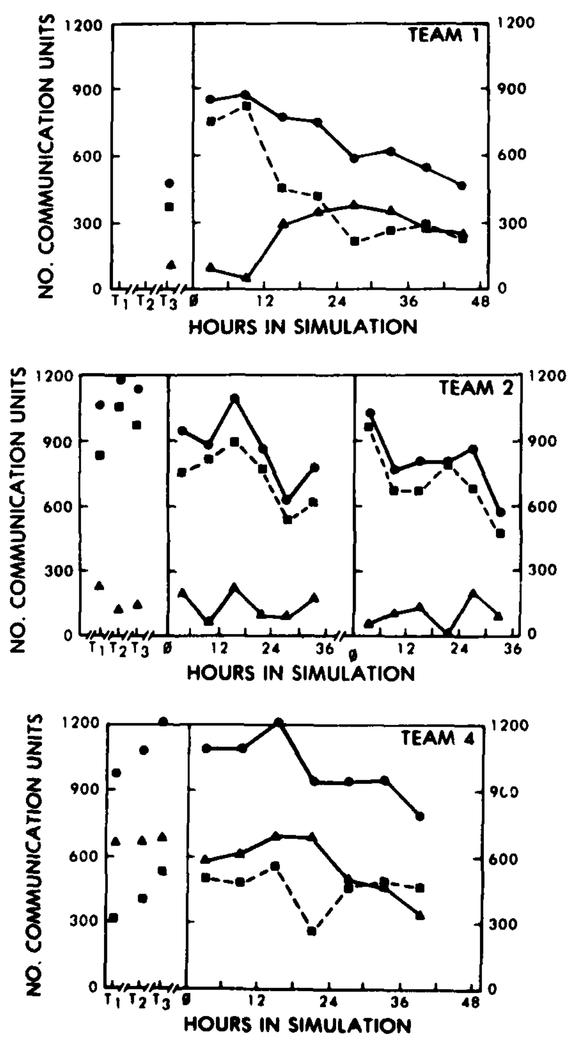
Table I. Percentages of various uncompleted preplanned target tasks. Values for the initial 36 h in the simulation are shown for the 4 Teams studied. Second challenge, 36 h comparisons are also shown for Teams 2 & 3. For Teams 1 & 4, 48 h comparisons are also indicated. Team 4's values for 45-48 h (interval after Team 4 discontinued) were extrapolated.

TEAM	PREPLANNING	PRIORITIZING	REVISING	UPDATING	% TOTAL TARGET PROCESSING NEVER COMPLETED
		INITIAL 36 HOUR COMPARISON (CHALLENGE 1)			
1	4	8	4	100	21
2	2	5	0	12	4
3	9	10	0	36	12
4	9	27	28	86	30
		SECOND 36 HOUR COMPARISON (CHALLENGE 2)			
2	2	11	0	11	6
3	12	7	0	19	10
		INITIAL 48 HOUR COMPARISON			
1	11	14	14	95	26
4	19	34	49	88	40

COMMUNICATION ANALYSES

Figure 3 shows total team CU for Teams 1, 2, and 4 each 6 h during the two lulls. Task SOP and All Other CU components are also shown. Total communications declined with increasing h in all three teams. Maximum CU ranged from 850-1200 (two lulls combined). Minimum values for each team were approximately 50% of maximum.

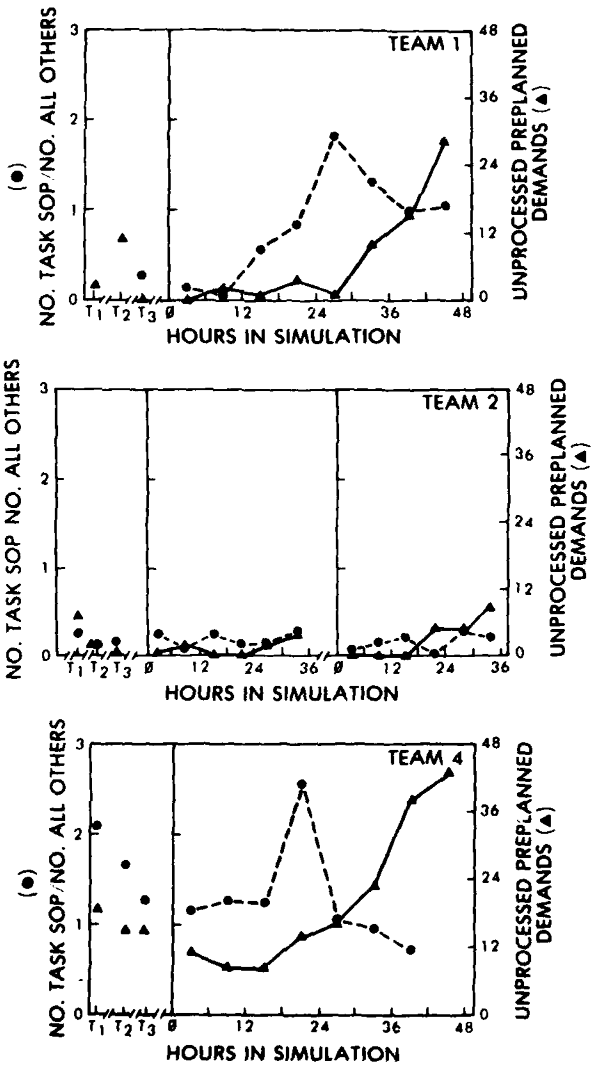
Figure 3. Group communication units (CU) during two 12-min lulls each 6 h are shown as a function of increased h in the simulation. Total CUs (solid circles), Task SOP CUs (solid triangles), and All Other CUs (solid squares) are shown.



Shown in Figure 4 are unprocessed preplanned demands and task ratio functions for each team with h in the simulation. The former measure is the total number of targets not completed from the preplanning, prioritizing, and revising tasks; the latter indicates the relative preponderance of Task SOP CU to All Other CU. Larger ratios generally occurred when a team had preplanning activities to perform during the lulls.

The teams differed markedly in how lulls were used. Teams 1 and 4 are similar but unlike Team 2. Team 2 used the lulls to rest and to interact with each other. In contrast, after 12 h Teams 1 and 4 engaged heavily in Task SOP CU. This is shown dramatically by the fact that Team 2's ratios were typically ≤ 0.3; whereas, after 12 h, Team 1's ratios were always ≥ 1.0, except in the final hours prior to termination. In Teams 1 and 4, increased unprocessed demands were evident after 30 and 18 h; however, increases in the task ratio preceded these performance changes. With increased unprocessed preplanning demands, communications became more task-oriented for Teams 1 and 4 up to some limit. Thereafter, the ratios decreased although both teams had increased amounts of unprocessed demands. Hence, after 24-30 h Task SOP CU decreased in spite of increasing backlogs which eventually resulted in dramatic operational failures. The decreases in task-related communications reflected the fact that fewer and fewer task communications followed SOP and individuals began to discuss other topics. Although teams often remained concerned with task requirements, their behaviors were much less goal directed and their nonstandard "tasks" communications reflected this. Such deviations sometimes resulted in confusion; increased effort and attention were then required for processing task demands.

Figure 4. Task ratios (solid circles) and number of unprocessed preplanned demands (solid triangles) are shown for Teams 1, 2 and 4 as a function of h in the simulation. Unprocessed preplanned demands are the sum of any revising, preplanning, and prioritizing targets which were not completed by each team. Increased task ratios indicate a greater preponderance of Task SOP CU to All Other CU.



Team 2's data are in marked contrast to those just described. At 36 h (second challenge) unprocessed demands were comparable to those for Team 1, yet changes in the task ratio were not observed. It was cited previously the single 86 h challenge took an earlier and greater toll on Teams 1 and 4 and that Team 2 was more proficient at preplanning. It appears that Team 2 had more reserve capacity and was able to maintain their preplanning without using the lulls. Their ratio was never > 0.3 at any time. Other communication (interaction) data for Team 2 (not shown) indicate that 18-30 h in the second challenge CU showing negative affect increased almost 200%, a level even greater than that observed after 36 h in the first challenge. Positive affect CU dropped to an unprecedented low after 24 h. In fact, after appraising their multiple mission sequence performance at 27 h, Team 2 members expressed doubts about their ability to finish the challenge. This was a remarkable display of self-and team-doubts since Team 2 completed the first challenge and knew the second was the same duration. These communication trends contrast with those from Team 2's first challenge and correlate with Team 2's deteriorations in preplanning and prioritizing.

Increased Task SOP CU were a likely compensatory reaction. They resulted from reduced individual and team efficiency and the recognition that more preplanning demands remained uncompleted. In Teams 1 and 4, increased task ratios were evident by 30 and 18 h, before unprocessed demands increased substantially. Later, when each team's compensations were no longer adequate to oppose the increased amounts of uncompleted demands, compensatory behaviors were reduced. This occurred perhaps to conserve, knowing that only 24-30 h of the simulation were completed, or perhaps these demands have physiologic or neuroendocrine costs which must be repaid. Biochemical and physical fitness data for Teams 1 and 2 (6) documented different patterns of response for each team; analogous data were not collected for Team 4.

These data suggest that teams and their predominant activities can be characterized by communications occurring during "lull" intervals. Furthermore, the number and type of communications bear some relationship to operational and performance capabilities. In the future, the contributions of various individuals to each group's communications will be explored. Ultimately, other indices will be arrayed with the operational performance data to determine if behavioral, biochemical, and social variables are correlated with operational capabilitites in small Army teams.

4. CONCLUSIONS

1. Teams 1 and 4 ended their participation in the simulation at times corresponding to their physiological lows. Instruction, experience, leadership and social support can probably attenuate these physiological effects.

2. Performance changes suggest the initial 36 h of the 86 h single sustained operations challenge (Teams 1 & 4) were more demanding than equivalent durations during the two, 38 h repeated challenges (Teams 2 & 3). Performance deteriorations occurred earlier and were greater. The implied mission demands, self- and team-doubts, and uncertainties associated with the anticipated 86 h challenge were likely contributing factors.

3. Performance deterioration appeared in most teams after 30-36 h in the simulation. Adverse environments, real-world situational uncertainties, and combat conditions would likely have additional disruptive influences.

4. Analyses of communications during lulls appear to provide useful correlates (predictors) of changes in team performance. Compensation and conservation reactions were also inferred.

5. This project methodology is adaptable to field research and training situations. The program suggests training, supervision, task, and medical issues for reducing the impact of sustained operations upon military personnel.

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6. ADDENDUM

The studies reported were conducted jointly by USARIEM, the Walter Reed Army Institute of Research (WRAIR), and the Naval Health Research Center (NHRC) in 1977. The professional, technical and administrative contributions of numerous individuals are acknowledged and greatly appreciated.

This information was presented as a paper at the 1980 Army Science Conference and was also published in the Proceedings of the Army Science Conference, 1980, Vol. 1, 167-181.

Human subjects participated in the studies after giving their free and informed voluntary consent. Investigators adhered to AR 70-25 and USAMRDC Regulation 70-25 on Use of Volunteers in Research.

The views, opinions, and/or findings contained in this report are those of the author(s) & should not be construed as an official Department of the Army position, policy, or decision, unless so designated by other official documentation.

APPENDIX

Table AI - Duties for Field Artillery Fire Direction Center (FDC) Personnel

TEAM MEMBER	DUTY CODE	MAJOR DUTIES
Radio-Telephone Operator (RTO)	10	receives, transmits, reads back information with radio sets
	11	requests caller authentication
	12	gives radio caller information (when rounds fired, when rounds will impact, when mission complete, etc)
	13	decodes radio messages
	14	communicates decoded information to appropriate individuals
Horizontal Control Operator (HCO)	20	plots targets or adjustments and shifts from known locations
	21	determines target range and direction
Vertical Control Operator (VCO)	20	plots targets or adjustments and shifts from known locations
	21	determines target range and direction
	22	determines altitude difference between target and guns
	23	calculates altitude correction, i.e. site
	24	plots unit location and direction of movement
Computer (COM)	31	communicates fire commands to guns
	32	calculates ballistic correction factors
	33	calculates gun tube displacement (lateral and vertical)
	34	plots meteorological correction factors on graphical firing tables
	35	specifies priority target data to guns
	36	sends preplanned target data to guns
	37	cancels old preplanned targets
	38	sends updated ballistic data to guns
Fire Direction Officer (FDO)	41	specifies fire commands for guns
	42	calculates ballistic correction factors
	43	calculates gun tube displacement (lateral and vertical)
	44	plots meteorological correction factors on graphical firing tables

NOTE: Duty codes are used in another Table.

Table A II - Major Mission Demands, FDC Duties, Urgency of Required Actions, Reponsible Personnel, and Feedback Criteria

MAJOR MISSION DEMANDS	No.	REQUIRED ACTIONS[1] IMMEDIATE	REQUIRED ACTIONS[1] DELAYED	MAJOR DUTIES[2, 3] RTO	MAJOR DUTIES[2, 3] HCO	MAJOR DUTIES[2, 3] VCO	MAJOR DUTIES[2, 3] COM	MAJOR DUTIES[2, 3] FDO	FEEDBACK GIVEN?	NEGATIVE FEEDBACK CRITERIA[4] ACCURACY (DEV. ≥ MILS)	NEGATIVE FEEDBACK CRITERIA[4] LATENCY (≥ SEC)
1. UNPLANNED MISSIONS											
a) Initial Target	4	1,2,3,4,5	——	10,11,12	20,21	20,21	31,32,33	42,43	YES	30	120-180
b) Subsequent Adjusts	22	1,2,3,4,5	——	10,12	20,21	20,21	31,33	43	YES	30	60-90
2. PREPLANNING (Encoded Message Targets)	28	1	1,2,3,4,5	10,11,13,14	20,21	20,21,22,23	32,33,36,37	42,43	NO	NA	NA
3. PRIORITIZING (Priority Targets)	22	1,4	——	10,11	——	——	35	——	NO	NA	NA
4. ON CALL MISSIONS											
a) Preplanned Target	16	1,4,5	——	10,11,12	——	——	31	——	YES	30	20-60
b) Subsequent Shifts	8	1,2,3,4,5,	——		20,21	20,21	31,32,33	42,43	YES	30	60
5. REVISING (Caused By Battery Moves)	12	——	2,3,4,5	——	21	21,22,23	32,33,36	42,43	NO	NA	NA
6. UPDATING (Caused by Weather Changes)	12	1	4,5	10	——	——	34,32,33,38	44,42,43	NO	NA	NA
7. MULTIPLE SESSION SEQUENCES											
a) Unplanned Missions	variable	1,2,3,4,5,	——	10,11,12	20,21	20,21	31,32,33	42,43	YES	30	60-180
b) On Call Missions	7 - 9	1,2,3,4,5	——	10,11,12			31		YES	30	20-60
c) Nonstandard Missions	variable	1,2,3,4,5	——	10,11,12	20,21	20,21	31,32,33	41,42,43	NO	NA	NA
d) Adjusts & Shifts	15 - 23	1,2,3,4,5	——	10,12	20,21	20,21	31,32,33	42,43	NO	NA	NA
8. POSITION REPORTS	9	1	1,3	10,11,13,14	——	24	——	——	NO	NA	NA
9. LULLS (No New Mission Demands)	2	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
10. NONSTANDARD MISSIONS	6 - 8	1,2,3,4,5	1,2,3,4,5	10,11,12,13,14	20,21	20,21,22,23	31,32,33	41,42,43	NO	NA	NA

FOOTNOTES:

[1]Team Member Codes
1 = RTO
2 = HCO
3 = VCO
4 = COM
5 = FDO

[2]Duty Codes (See Personnel Duties Table)

[3]Work-breakdown structure assumes teams followed SOP and they were also current in their preplanning.

[4]The most demanding criteria are shown; additional negative feedback for continued inadequacy on a mission would also be given.

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